

STIMULUS GENERALIZATION OF BEHAVIORAL HISTORY

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Undergraduates responded under a variable-ratio 30 schedule in the presence of a 25-mm long line and on a differential-reinforcement-of-low-rate 6-s schedule when a 13-mm long line was present. Following this, a line-length continuum generalization test was administered under a fixed-interval 6-s schedule (Experiment 1) or extinction (Experiment 2). In both experiments, obtained generalization gradients conformed to typical postdiscrimination gradients. Responses were frequent under stimuli physically similar to the 25-mm line and infrequent under stimuli physically similar to the 13-mm line. The generalization gradients were generally asymmetric with peak response rates occurring at line lengths greater than 25 mm.

Key words: behavioral history, stimulus generalization, variable-ratio schedules, differential-reinforcement-of-low-rate schedules, fixed-interval schedules, screen touch, humans

The experimental analysis of behavior has focused on current contingencies as primary variables affecting the behavior of organisms. Recently, however, some investigators have paid attention to the effects of historical contingencies on current behavior (cf. Tatham & Wanchisen, 1998). The present study provides some evidence that the effects of behavioral history are generalized across stimuli.

Behavioral history effects are observed when past experiences exert control over present behavior thereby reducing the control exerted by current contingencies (Freeman & Lattal, 1992). For example, Weiner (1964, 1969) found that humans responded differently under identical fixed-interval (FI) schedules of reinforcement depending on the schedules to which they had previously been exposed. Subjects with histories of fixed-ratio (FR) schedules responded at high rates under the FI schedules, whereas those with differential-reinforcement-of-low-rate (DRL) schedule histories responded at low rates under the same FI schedules. Similar effects have been demonstrated with nonhuman an-

imals under different conditions (e.g., Nader & Thompson, 1987; Urbain, Poling, Millam, & Thompson, 1978; Wanchisen, Tatham, & Mooney, 1989).

Behavioral history effects most often have been compared across subjects by providing different histories to different groups of subjects (e.g., Baron & Leinenweber, 1995; Cohen, Pedersen, Kinney, & Myers, 1994; Cole, 2001; Johnson, Bickel, Higgins, & Morris, 1991; LeFrancois & Metzger, 1993; Nader & Thompson, 1987, 1989; Poling, Krafft, & Chapman, 1980; Urbain et al., 1978; Wanchisen et al., 1989; Weiner, 1964, 1969). Freeman and Lattal (1992), however, developed a within-subject technique for examining the effects of experiences with different schedules of reinforcement. In their experiments, pigeons were initially exposed to FR and DRL schedules under different stimulus conditions; a single schedule was arranged in each session and sessions were separated by 6 hr. Following this, an FI (Experiment 1) or variable-interval (VI, Experiment 2) schedule with an interval value yoked to the common FR and DRL interreinforcement interval (IRI) was arranged in the presence of the stimuli previously correlated with the two schedules. They found that response rates under the FI or VI schedule were transitionally higher in the presence of the stimuli that had previously been correlated with the FR schedule than in the presence of the stimuli previously correlated with the DRL schedule.

These results have been replicated across stimuli, schedules, and species. Pigeons' response rates under a VI schedule were higher

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in the presence of a stimulus previously correlated with a differential-reinforcement-of-high-rate (DRH) schedule than in the presence of a stimulus previously correlated with a DRL schedule (Ono & Iwabuchi, 1997). Likewise, human response rates under an FI schedule were differentiated across verbal stimuli previously correlated with FR and DRL schedules (Okouchi, 1999).

The technique of Freeman and Lattal (1992) permits a within-subject assessment not only of whether responding carries over from the previous schedule to the subsequent schedule, but also of whether these history effects persist. Whether or not a history of responding on one schedule of reinforcement has a lasting effect on responding on another schedule is still one of the controversial issues in the study of behavioral history effects (Cole, 2001). Some research suggests that performances under current schedules are irrevocably affected by prior exposure to the previous schedules (Johnson et al., 1991; LeFrancois & Metzger, 1993; Urbain et al., 1978; Wanchisen et al., 1989; Weiner, 1964, 1969), whereas other research suggests only transitory effects of schedule history (Baron & Leinenweber, 1995; Cohen et al., 1994; Cole, 2001; Freeman & Lattal, 1992; Okouchi, 1999, 2003). A within-subject comparison may contribute to this issue by directly examining the duration of behavioral history effects. For example, Freeman and Lattal found in their Experiment 1 that response rates for each of 3 pigeons under an FI schedule were higher in the presence of the former FR stimuli than in the presence of the former DRL stimuli for the first 18, 25, or 41 sessions.

Together with developing a technique for comparing different behavioral history effects within individual subjects, the Freeman and Lattal (1992) study has two interrelated implications on history effects. First, as Freeman and Lattal suggested, the results demonstrate that the history effects were under stimulus control. Second, the results raise the question of whether history effects can be generalized along one or more dimensions of the stimulus. In the behavioral history literature, however, no studies have ever obtained generalization gradients of antecedent stimuli.

Although the research focus was on stim-

ulus properties of the schedules, Okouchi's (2003) study may relate to the present issue. Okouchi initially exposed humans to a mixed FR DRL schedule, the values of which were adjusted so that IRIs in one component were longer than those in the other component. Following this, FI schedules with six different values were in effect. Response rates under the FI schedules were higher when the IRIs approximated those produced under the FR schedule, whereas the rates were lower when the IRIs approximated those produced under the DRL schedule. Thus Okouchi's results suggest that the history effects (i.e., responding at high or low rates) were generalized from the training IRIs to the testing IRIs. These findings suggest that history effects may be generalized across antecedent stimuli.

The present study examined generalization of behavioral history effects across antecedent stimuli in human subjects. Undergraduates were exposed first to a variable-ratio (VR) schedule in the presence of a stimulus from a set of 11 horizontal lines that differed in length and to a DRL schedule in the presence of a different line from the same set. Following this training, stimulus control and generalization of these schedule histories were examined by presenting each of the 11 horizontal lines. This test was conducted under an FI schedule, which is one of the most frequently used schedules for testing history effects (e.g., Nader & Thompson, 1989; Urbain et al., 1978; Weiner, 1964). If responding under the FI testing schedule changed as a function of physical similarity between stimuli presented with the training and testing schedules, the history effects would have been generalized across these antecedent stimuli.

The present study also examined the persistence of behavioral history effects. Previous within-subject comparisons have found that response rates that were differentiated in the presence of stimuli formerly accompanying the FR and DRL schedules converged with continued FI or VI exposure (Freeman & Lattal, 1992; Okouchi, 1999). The present study examined response rates in the presence of the stimuli that had previously been correlated with VR and DRL schedules and examined the shape of the generalization gradients with continued exposure to the testing schedule.

EXPERIMENT 1

METHOD

Subjects

Five female undergraduates recruited from an educational psychology class at Osaka Kyoiku University served as subjects. They were 19 to 20 years old, and none had experience with operant conditioning experiments.

Apparatus

The experimental room was 1.70 m wide, 2.20 m deep, and 2.17 m high. A Nihon Electric Company PC-9821AP microcomputer, located in an adjacent room, was used to control the experiment. The subject sat at a desk facing a color display monitor (250 mm wide by 180 mm high) equipped with a Micro Touch Systems® touch screen. A filled white circle (55 mm diameter) was presented in the center of the black screen, and each touch on the circle (operandum) was defined as a response. One of 11 different horizontal black lines ranging in length from 10 mm to 40 mm and 5 mm high was superimposed on the center of the circle (cf. O'Donnell & Crosbie, 1998; O'Donnell, Crosbie, Williams, & Saunders, 2000). All interevent times were recorded in real time, with 50-ms resolution. A second white circle (30 mm diameter) was presented at the bottom left of the monitor. Each touch to the circles was accompanied by a brief sound through a speaker beneath the desk. A point counter was located at the top right of the monitor.

Procedure

Subjects were required to sign an informed consent agreement that specified the frequency and duration of their participation and the average earnings for such participation. The subjects were asked, and agreed, to remain in the experiment for a maximum of six 90-min experimental periods, and actually participated in three experimental periods. A 90-min experimental period was conducted once per day, two times per week. During this period, a maximum of six variable-duration sessions occurred. Sessions were separated by 2- to 3-min breaks. Upon completion of the experiment, subjects were paid for their participation (100 yen per 90 min—approx-

mately 0.95 U.S. dollars) and performance (2 yen per 100 points) and were debriefed. The overall earnings for each subject ranged from 1,982 to 2,227 yen.

On the first day of the experiment, each subject was asked to silently read the following instructions (translated from Japanese to English):

Your task is to earn as many points as you can. A hundred points are worth two yen. In addition, you will be paid 100 yen for every day you spend in the experiment. Total payment will be made at the end of the experiment. A circle will be shown in the center of the display monitor. If you touch the circle, the center circle may disappear, then a small circle will appear in the bottom of the display monitor. By touching the small circle, you can earn points. Accumulated points will be shown in the top right of the display monitor.

However, you should remember that touching the center circle does not always turn off the circle. Touching the center circle sometimes works, and sometimes does not work.

The words READY and GO will appear in sequence on the display monitor. When the word GO disappears, do the task until the words GAME OVER appear on the display monitor.

During the task, the word WAIT may appear on the display monitor. When this word appears, please wait until the center circle reappears.

The typed set of instructions remained on the desk throughout the experiment. Questions regarding the experimental procedure were answered by telling the subject to reread the appropriate sections of the instructions. Then the words READY and GO were presented in sequence in the top left of the display monitor. After the word GO disappeared, a circle, which served as the operandum, was presented in the center of the display monitor.

When the schedule requirement was met, the center circle was darkened, and the circle for the consummatory response was presented at the bottom left of the monitor. A touch during a 3-s consummatory response period darkened the circle and accumulated 100 points on the counter. If the subject did not touch the circle during this period, no points were delivered (subjects never failed to meet this contingency).

Multiple schedules were used. The interval

between components of the multiple schedules was 5 s, during which the word WAIT was presented at the top left of the monitor. After the session terminated, the words GAME OVER appeared at the top left of the monitor.

During an initial 13-session training condition, a multiple VR DRL schedule was in effect. The VR and DRL schedules were correlated with, respectively, a 25-mm and a 13-mm long horizontal line superimposed on the center circle. The initial VR and DRL schedule values were five responses and 1 s, respectively, and these were increased progressively over nine sessions. That is, the values for the VR and DRL schedules in the first, second, third, and fourth sessions were 5 responses and 1 s, 5 responses and 2 s, 10 responses and 3 s, and 10 responses and 6 s, respectively. For Sessions 5 through 8, a multiple VR 20 DRL 6-s schedule was in effect. For the last five sessions of the training condition, the VR and DRL values were set at 30 responses and 6 s, respectively.

During the first six sessions of the training condition, each multiple-schedule component was presented once per session and lasted until 20 reinforcers occurred. The order in which the two components were presented was random, with the restriction that the same order did not occur for more than three consecutive sessions. In the last seven sessions of the training condition, each component lasted for 20 s and 22 components were presented in a session. The 20-s component timer stopped when the consummatory response was made available and was restarted when the center circle of the operandum reappeared. The order of the VR and DRL multiple schedule components was random, with the restriction that the same schedule did not occur for more than three consecutive components and that an equal number of VR and DRL components were completed each session.

Following the training condition, a line-length continuum generalization test was administered under an FI 6-s schedule. Each of the following 11 lines was presented 12 times: 10, 13, 16, 19, 22, 25, 28, 31, 34, 37, and 40 mm. These 132 presentations were arranged in 12 blocks, each of which included the 11 different stimuli in a randomized order (Guttman & Kalish, 1956). Each stimulus pre-

Table 1

Mean response rate and mean number of reinforcers (ranges in parentheses) in each component of the multiple VR 30 DRL 6-s schedule in the last three sessions of the training condition in Experiment 1.

Subject	Responses per minute		Reinforcers per session	
	VR 30	DRL 6 s	VR 30	DRL 6 s
1	255.3 (242.8–270.3)	8.4 (7.9–8.7)	32.3 (31–34)	24.0 (23–25)
2	264.3 (242.9–289.3)	38.9 (31.9–52.6)	30.3 (29–33)	13.7 (9–17)
4	374.1 (354.9–388.0)	14.4 (13.4–15.8)	45.7 (45–47)	19.3 (18–21)
9	341.7 (283.5–425.9)	16.7 (13.1–19.6)	40.0 (32–50)	20.7 (18–22)
10	375.4 (354.3–397.6)	22.9 (6.0–54.0)	24.3 (20–33)	19.3 (18–20)

sentation was of 20-s duration, separated by a 5-s waiting period. The 20-s component timer stopped during the consummatory response period.

RESULTS

Table 1 shows the mean response rate and the mean number of reinforcers in each schedule component for the last three sessions of the training condition for each subject (these means are represented graphically in Figure 1). Response rates for all subjects were higher in the VR schedule component than in the DRL component. Responding produced reinforcers frequently in both schedule components for all subjects. Thus consistent response-rate differentiation was established by the contingencies of the multiple VR DRL schedule.

Figure 1 shows, for each subject, the mean response rates in the presence of each test stimulus as a function of length of the stimulus during the first four blocks of the testing condition. For all subjects, response rate in the presence of the 25-mm line (previously correlated with the VR schedule) was higher than responding in the presence of the 13-mm line (previously correlated with the DRL schedule), suggesting stimulus control of VR and DRL histories. For all subjects except Subject 4, responding in the presence of the 22- and 28-mm lines, which were closest to the former VR stimulus, was higher than rates emitted in the presence of the 10- and 16-mm lines (closest to the former DRL stimulus),

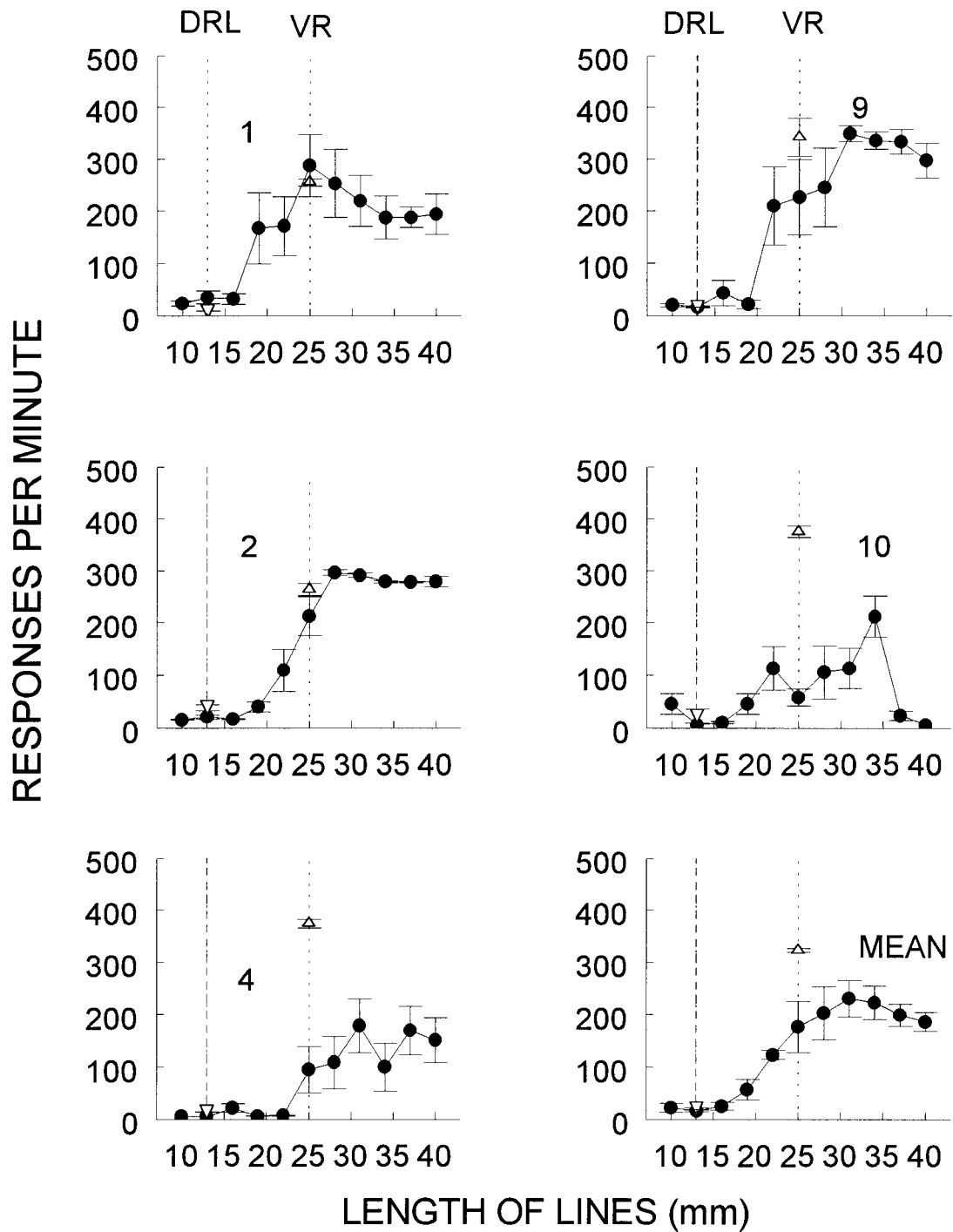


Fig. 1. Mean response rates of individual subjects in the presence of all 11 line lengths during the first four blocks of the generalization test in Experiment 1. The group mean is shown in the bottom right panel. Vertical lines marked VR and DRL identify the line lengths that were correlated with VR 30 and DRL 6-s schedules during the training condition. Triangles and inverted triangles represent mean response rates in the last three sessions of the training condition under the VR and the DRL schedules, respectively. Bars around points represent standard errors.

suggesting that responding was generalized within stimuli physically closest to the training stimuli and differentiated among the physically furthest stimuli. For all subjects, response rates were distributed away from stimuli previously correlated with the DRL schedule.

Figure 2 shows the mean response rates in the presence of each test stimulus during the last four blocks of the testing condition. For Subjects 1, 4, and 10, there was no systematic relation between response rates and line lengths. By contrast, the generalization gradients obtained in the first four test blocks remained in the last four blocks for Subjects 2 and 9.

DISCUSSION

Generalization gradients obtained in testing under the FI schedule generally conformed to typical gradients obtained under extinction after discrimination training (Hanson, 1959). First, the gradients show a uniform and orderly relation to the stimulus dimension. Responding was frequent in the presence of stimuli physically similar to the stimulus previously correlated with the VR schedule and was infrequent when lines similar in length to the DRL stimulus were presented. Second, the gradients were asymmetric. Responses were distributed on the side in which the stimulus correlated with low-rate responding was not located, indicating peak or area shifts.

Experiment 1 tested stimulus generalization of behavioral history effects under an FI schedule. Most investigators focusing primarily on history effects have used schedules of intermittent reinforcement during testing (e.g., Baron & Leinenweber, 1995; Barrett, 1977; Cole, 2001; Freeman & Lattal, 1992; Johnson et al., 1991; LeFrancois & Metzger, 1993; Nader & Thompson, 1987, 1989; Okouchi, 1999, 2003; Ono & Iwabuchi, 1997; Poling et al., 1980; Urbain et al., 1978; Wanchisen et al., 1989; Weiner, 1964, 1969; but see Cohen et al., 1994). Experiment 2, by contrast, attempted to replicate the results of Experiment 1 using experimental extinction as a testing schedule. Extinction has been used as a standard testing schedule within the stimulus generalization literature (e.g., Guttman & Kalish, 1956; Hanson, 1959). In the context of the research in resistance to change (e.g.,

Nevin, 1974), resurgence (e.g., Epstein, 1985), or schedule insensitivity (e.g., Hayes, Brownstein, Zettle, Rosenfarb, & Korn, 1986), history effects have often been tested under experimental extinction. Thus extinction allows an examination of whether the present procedure is sound as a generalization experiment and whether the history effects obtained in Experiment 1 may be replicated under a different testing schedule.

EXPERIMENT 2

METHOD

Subjects and Apparatus

One male (Subject 9) and 4 female undergraduates, 19 to 21 years old, participated. Details of subject screening, informed consent, subject payment, and apparatus were identical to those employed in Experiment 1.

Procedure

Details of the procedure were as described in Experiment 1, with the exception that generalization tests were administered under experimental extinction.

Subject 8 required additional DRL schedule training when contingencies were changed such that each multiple schedule component terminated after 20 s regardless of the number of obtained reinforcers. Response rates under the DRL schedule for this subject increased, producing no reinforcers in Sessions 7 through 11 and only one reinforcer in Session 12. A decreased DRL value (multiple VR 30 DRL 3 s) in Session 13 increased the rate of reinforcement in the DRL component. Thereafter, Subject 8 maintained response-rate differentiation between the VR and DRL schedule components under the multiple VR 30 DRL 3-s schedule in Session 14 and the multiple VR 30 DRL 6-s schedule in Sessions 15 through 19. Thus Subject 8 participated in a total of 19 training sessions and one testing session across four experimental periods, whereas the others finished the experiment with three experimental periods.

RESULTS

Table 2 and Figure 3 show that, just as in Experiment 1, response rates for all subjects during the last three sessions of the training

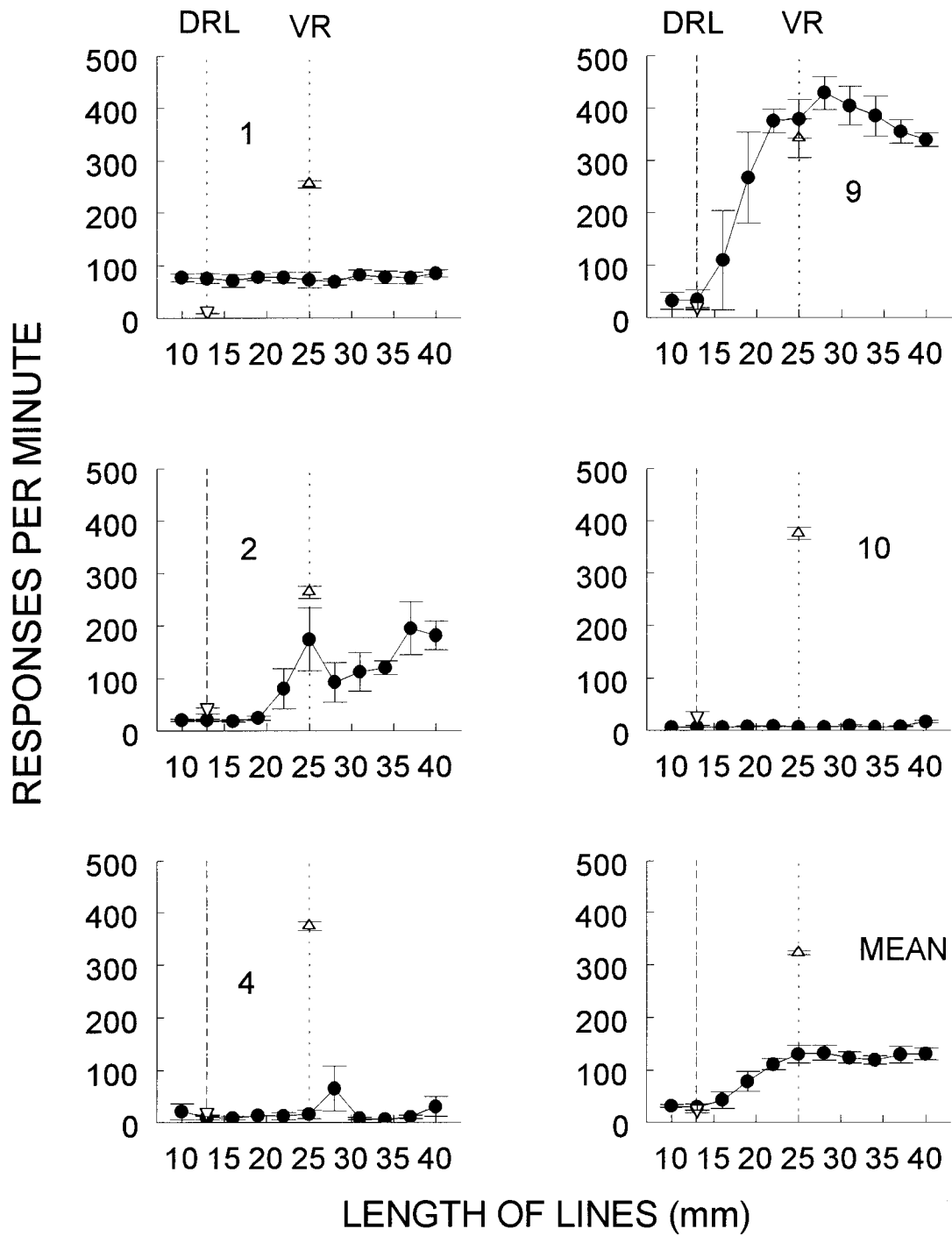


Fig. 2. Mean response rates of individual subjects in the presence of all 11 line lengths during the last four blocks of the generalization test in Experiment 1. Details as in Figure 1.

Table 2

Mean response rate and mean number of reinforcers (ranges in parentheses) in each component of the multiple VR 30 DRL 6-s schedule in the last three sessions of the training condition in Experiment 2.

Subject	Responses per minute		Reinforcers per session	
	VR 30	DRL 6 s	VR 30	DRL 6 s
3	170.0 (152.7–188.9)	14.6 (14.2–15.0)	21.7 (19–25)	20.0 (19–21)
5	217.1 (80.6–318.0)	28.3 (14.7–54.7)	27.7 (13–37)	20.0 (19–20)
6	340.9 (307.5–367.8)	15.1 (14.7–15.3)	41.3 (37–46)	21.7 (21–22)
7	90.4 (79.0–97.0)	5.5 (4.9–6.0)	10.3 (8–12)	18.7 (18–20)
8	160.0 (131.7–178.8)	10.8 (8.2–13.6)	19.0 (16–21)	19.0 (17–23)

condition were higher in the VR schedule component than in the DRL component, and that responding frequently produced reinforcers in both schedule components.

Figure 3 shows the mean response rates for individual subjects in the presence of each test stimulus as a function of line length during the first four blocks of testing. For all subjects except Subject 3, higher response rates were emitted in the presence of the stimulus previously correlated with the VR schedule than when the DRL stimulus was present. With the exception of Subject 7, higher response rates were emitted in the presence of the 22- and 28-mm lines (closest to the former VR stimulus) than when the 10- and 16-mm lines (closest to the former DRL stimulus) were presented. For all subjects, the response gradient was shifted away from the DRL stimulus.

Figure 4 shows the generalization gradient during the last four blocks of the test. For all subjects except Subject 6, the responses were distributed away from the DRL stimulus. In general, as in Experiment 1, generalization gradients of the last four blocks of the test were flatter than those of the first four blocks.

DISCUSSION

Compared with the results of Experiment 1, the generalization gradients were flatter and less systematic. Nevertheless, orderly gradients were obtained for each subject. Generalization gradients obtained under extinction also had the aforementioned critical

features of typical postdiscrimination gradients (Hanson, 1959). Responding was frequent in the presence of stimuli physically similar to the stimulus previously correlated with the VR schedule and was infrequent when lines similar in length to the DRL stimulus were presented, and the peak of the gradient was shifted beyond the VR stimulus in the direction opposite the DRL stimulus. Thus the results of Experiment 2 replicate those of Experiment 1, demonstrating that the present procedure was sound for examining generalization gradients and that behavioral history effects were generalized when extinction was programmed during testing.

GENERAL DISCUSSION

In previous experiments with pigeons (Freeman & Lattal, 1992; Ono & Iwabuchi, 1997) and humans (Okouchi, 1999), response rates under FI or VI schedules were higher in the presence of stimuli previously correlated with FR or DRH schedules than when stimuli previously correlated with DRL were present. These findings were systematically replicated in the present experiments involving human subjects. Response rates under an FI schedule (Experiment 1) or extinction (Experiment 2) were higher in the presence of a stimulus previously correlated with a VR schedule than under a stimulus that had been correlated with a DRL schedule.

The present results also demonstrate that these history effects were generalized. Okouchi (2003) found that response rates under FI schedules were higher when the IRIs approximated those produced under the previous FR schedule, and the rates were lower when the IRIs approximated those produced under the previous DRL schedule, suggesting the history effects were generalized across the IRIs. In the present experiments, response rates under an FI schedule or extinction were higher when stimuli physically approximating the former VR stimulus were present, and the rates were lower when stimuli physically approximating the former DRL stimulus were present. Extending the findings of Okouchi, therefore, the present results indicate that history effects generalized across the antecedent stimuli.

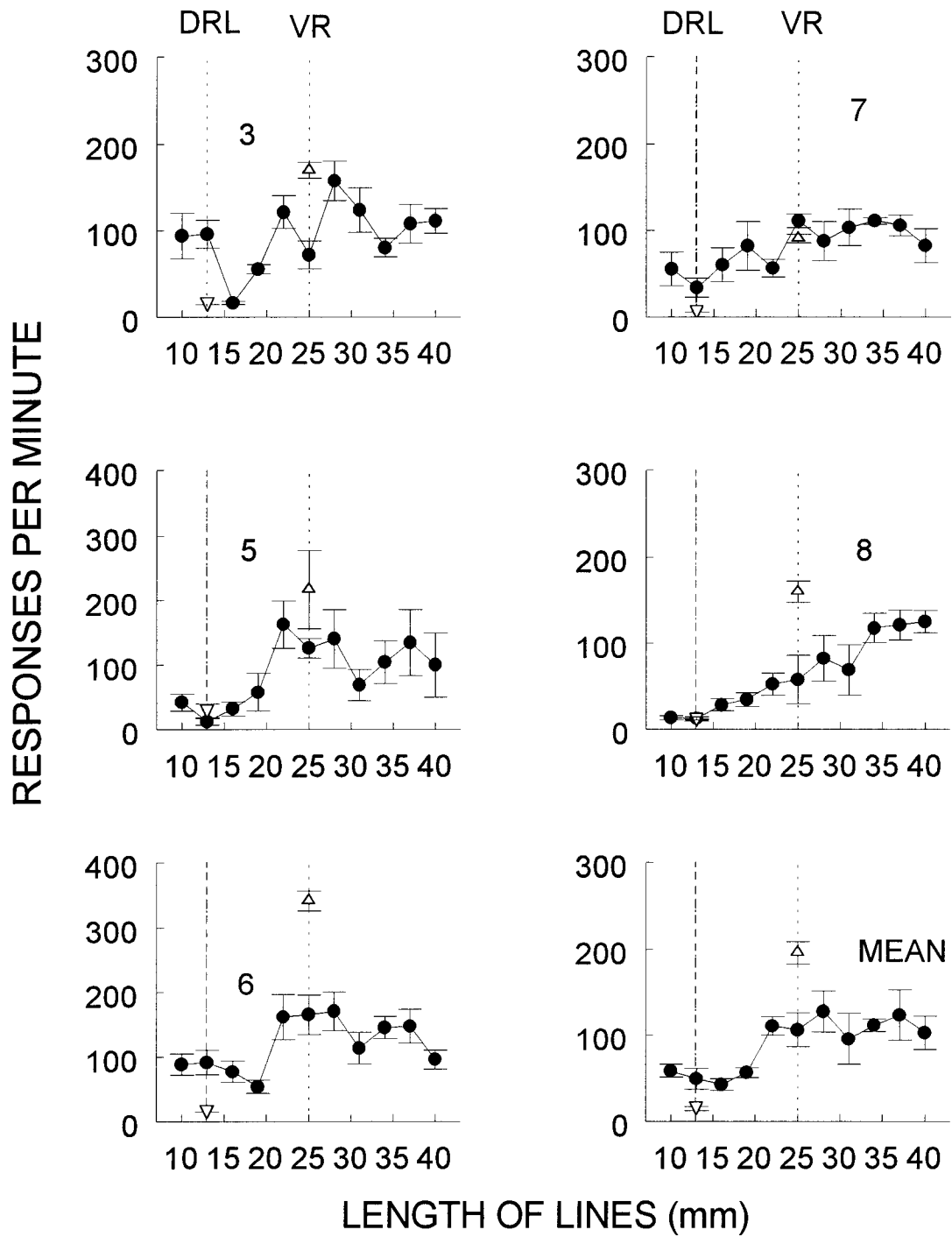


Fig. 3. Mean response rates of individual subjects in the presence of all 11 line lengths during the first four blocks of the generalization test in Experiment 2. Details as in Figure 1.

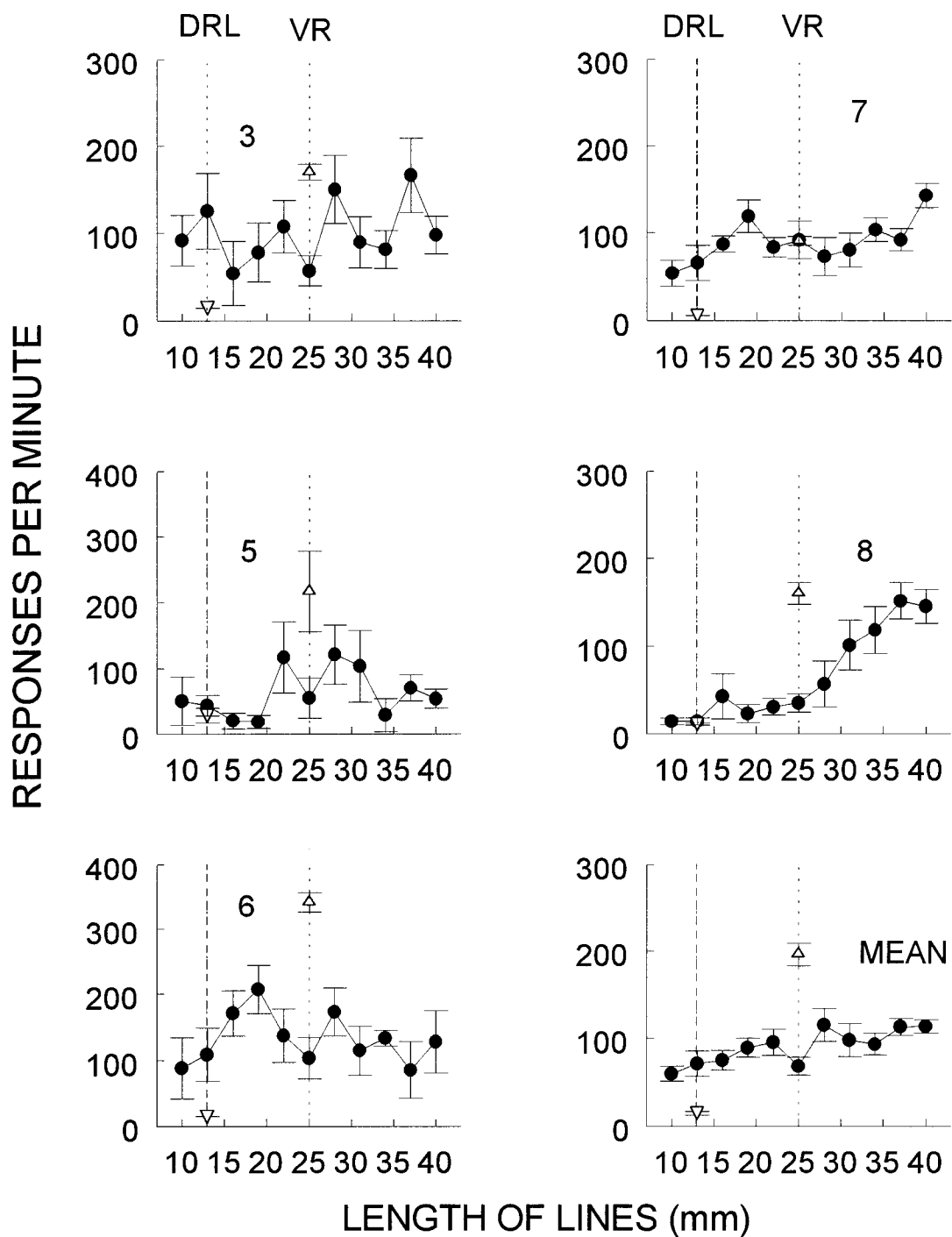


Fig. 4. Mean response rates of individual subjects in the presence of all 11 line lengths during the last four blocks of the generalization test in Experiment 2. Details as in Figure 1.

Most of the experimental literature on behavioral history effects has not used extinction as a testing schedule (e.g., Baron & Leinenweber, 1995; Barrett, 1977; Cole, 2001; Freeman & Lattal, 1992; Johnson et al., 1991; LeFrancois & Metzger, 1993; Nader & Thompson, 1987, 1989; Okouchi, 1999, 2003; Ono & Iwabuchi, 1997; Poling et al., 1980; Urbain et al., 1978; Wanchisen et al., 1989; Weiner, 1964, 1969). The definition of history effects (Freeman & Lattal, 1992), however, is so broad that there is no reason to exclude extinction from the schedules under which history effects might be assessed. Resistance to change (e.g., Nevin, 1974) or resurgence (e.g., Epstein, 1985) also refer to the effects of historical variables on present behavior that are observed under extinction, and they have been discussed in terms of their similarity with history effects (Cohen et al., 1994; Lieving, Doughty, Meginley, Horne, & Lattal, 2000). The present experiments obtained qualitatively similar generalization gradients under an FI schedule and extinction, thereby suggesting the generality of some results of behavioral history experiments across testing schedules including extinction.

Behavioral History Effects as Transition States

In both of the present experiments, generalization gradients tended to become flatter with continued exposure to the testing schedules, indicating diminishing effects of the VR and DRL schedule histories. Cole (2001) demonstrated with rats that the effects of FR and/or DRL schedule histories disappeared within 79 to 134 sessions under FI test conditions. Although the present subjects completed far fewer sessions, less differentiated response rates and flatter generalization gradients across the testing blocks suggest continued exposure to the FI or extinction test contingencies would have yielded even more homogenous response rates. Thus the present results are consistent with the view that behavioral history effects are transition states (Baron & Leinenweber, 1995; Cohen et al., 1994; Cole, 2001; Freeman & Lattal, 1992; Okouchi, 1999, 2003), and indicate that the transient effects were described by the generalization gradients.

The short-lived effects of behavioral histories in the present experiments also shed

light on one of the variables affecting response persistence following a contingency change: correlated changes in discriminative stimuli. Nader and Thompson (1987) reported that history effects are more quickly diminished when discriminative stimuli are changed along with the changes in the schedule contingencies. The most salient feature of the present procedures was generalization testing, which has not been used in previous experiments on behavioral history. In the present experiments, most of the line lengths presented in testing were similar, but not identical, to those presented in training. This disruption in the discriminative stimuli presented after the contingency change may have accelerated the flattening of the generalization gradients.

Discriminative or Categorical Control of Behavioral History Effects

Typical postdiscrimination gradients have gradually descending slopes on both sides of a shifted peak (e.g., Hanson, 1959). Although in the present data set most individual gradients conform to this typical shape, some gradients appear atypical. For example, response rates increased abruptly from the 22-mm to the 25-mm lines for Subject 4 in Experiment 1 (Figure 1), or increased as a function of line length with no descending trend on the right limb of the gradient for Subject 8 in Experiment 2 (Figure 3). Such gradients have also previously been found in a line-length continuum generalization with humans. Fields, Reeve, Adams, Brown, and Verhave (1997) found that a variety of line lengths around training stimuli produced sigmoidal rather than smooth generalization gradients for 4 of 6 subjects. In addition to sigmoidal gradients, O'Donnell et al. (2000) found gradients like that of Subject 8. These researchers suggested that the line lengths were categorized as long or short rather than discriminated along a continuum. Future studies using stimulus dimensions such as pure tones (Baron, 1973) that are more difficult to label than line length may isolate discriminative control from categorical control and extend the present finding of stimulus generalization of behavioral history effects.

Human Discriminated Responding under Multiple Schedules

The findings of the present experiments also may have implications for procedural variables affecting the establishment of stimulus control with humans under laboratory conditions. Stimulus control of differentiated response rates was established under a multiple schedule for all subjects in the present two experiments. These performances are consistent with those from nonhumans, but contrast with those typically reported in the human operant literature. For example, a considerable number of human subjects have failed to demonstrate differentiated response rates between the components of multiple FR DRL schedules when subjects were not instructed about response rates or contingencies (e.g., Hayes, Brownstein, Haas, & Greenway, 1986; Hayes, Brownstein, Zettle, et al., 1986; Rosenfarb, Newland, Brannon, & Howey, 1992; Wulfert, Greenway, Farkas, Hayes, & Dougher, 1994). By contrast, procedures employed in my laboratory have yielded consistent differentiation of response rates between the components of multiple (Okouchi, 1999) or mixed (Okouchi, 2003) FR DRL schedules. Okouchi (2003) speculated that human discriminated responding under multiple schedules might result from the changing criterion procedures used early in training. In the present experiments, subjects started training under a multiple VR 5 DRL 1-s schedule. Across nine training sessions, the VR and DRL values were increased resulting in a gradual increase in discriminated responding. Similar changing criterion procedures are common in nonhuman experiments (cf. Lattal, 1991) but have not been employed in the human research cited above that has reported extensive failures to establish multiple schedule control of discriminated response rates.

A second procedural difference that may play a role in human sensitivity to changing schedule contingencies is the practice of leaving multiple schedule components unchanged until a fixed number of reinforcers are obtained. In previous experiments that have produced undifferentiated response rates under multiple schedules (Hayes, Brownstein, Haas, et al., 1986; Hayes, Brownstein, Zettle, et al., 1986; Rosenfarb et al.,

1992; Wulfert et al., 1994), each multiple schedule component lasted for 120 s regardless of the number of reinforcers earned. Fixed-duration components, or sessions, do not ensure that behavior will contact the reinforcement contingency that may be necessary for establishing schedule control of behavior (Galizio, 1979). By contrast, multiple schedule components lasted until 30 reinforcers were obtained during all sessions of the Okouchi (1999) experiment, and until 20 reinforcers had been acquired during the first six sessions of the present experiments. These procedures were employed after pilot data suggested that fixed duration components did not yield differentiated multiple schedule performances even using the changing criterion procedure described above, and that switching to the practice of changing multiple schedule components only after a fixed number of reinforcers were obtained quickly established discriminated response rates. During the first six sessions of the present two experiments, the time spent earning 20 reinforcers ranged from 35.5 s to 1380.2 s (median = 145.6 s). Temporary deterioration of discriminated response rates occurred for Subject 8 in Experiment 2 when the criterion for determining component duration switched from the number of reinforcers delivered to a fixed component duration. These results also suggest the importance of the component duration ensuring contact with reinforcement contingencies necessary for establishing the multiple schedule control.

Sensitivity is synonymous with experimental control (Madden, Chase, & Joyce, 1998), which is one of the prime goals of the experimental analysis of behavior (Sidman, 1960, pp.16–23). Human behavior is often said not to be as affected by schedules of reinforcement when compared with the behavior of nonhuman animals (e.g., Baron, Kaufman, & Stauber, 1969; Hayes, Brownstein, Zettle, et al., 1986; Horne & Lowe, 1993). Some investigators, however, have obtained schedule-sensitive human behavior by attending to procedural variables responsible for establishing such control (e.g., Galizio, 1979; Madden & Perone, 1999; Matthews, Simoff, Catania, & Sagvolden, 1977). In the present experiments, human responding was sensitive to a multiple VR DRL schedule, and procedural

variables such as changing-criterion training procedures and contact with the schedule contingencies may have played a role in establishing this sensitivity. Future experiments using within-subject comparisons will contribute to identifying the importance of these variables for establishing human discriminated behavior.

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